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The Demographic Transition in Colombia: Theory and Evidence*

Daniel Mejía[†] Maria Teresa Ramirez[‡] Jorge Tamayo[§]

Abstract

The demographic transition from high to low mortality and fertility rates was one of the most important structural changes during the twentieth century in most Latin American economies. This paper uses a simple economic framework based on Galor and Weil (2000) for understanding the main forces behind this structural transition; namely, increases in the returns to human capital accumulation driven by continuous advances in productivity led families to reduce the number of offspring and increase the level of investment in their education. As a result, the economy transits from a stage of stagnation subject to Malthusian forces to a stage of sustained economic growth, where increases in productivity lead to improvements in living standards. We use available data for Colombia between 1905 and 2005 to test the main predictions of the model with time series analysis, finding empirical evidence in their favor.

Keywords: Economic Growth, Demographic Transition, Colombia.

JEL Classification Numbers: C32, J11, N36, O40, O54

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La transición demográfica en Colombia: Teoría y evidencia.*

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Abstract

Uno de los cambios estructurales más importantes ocurridos en los países latinoamericanos durante el siglo XX fue la transición demográfica, al pasar de altas a bajas tasas de mortalidad y fertilidad. Este artículo utiliza una simplificación del modelo de Galor y Weil (2000) para entender las principales fuerzas detrás de dicha transición, en la cual incrementos en los retornos a la acumulación de capital humano derivados de un continuo avance en la productividad lleva a las familias a reducir el número de hijos e incrementar la inversión en su educación. Como resultado, la economía se mueve de un estado de estancamiento sujeto a fuerzas Malthusianas a un estado de crecimiento económico sostenido, donde los incrementos en productividad llevan a mejoras en los estándares de vida. Para probar si las principales predicciones del modelo se cumplen para el caso colombiano se realiza un análisis de series de tiempo, encontrando evidencia empírica a su favor.

Palabras clave: Crecimiento económico, transición demográfica, Colombia.

Clasificación JEL: C32, J11, N36, O40, O54

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1 Introduction

One of the most important structural transformation in most Latin American economies during the twentieth century was the demographic transition. That is, the transition from high to low mortality and fertility rates. For instance, mortality rates in Colombia declined from roughly 23.4 deaths per thousand inhabitants in 1905 to about 13.2 in 1951 and about 5.5 by 2000. Similarly, the fertility rate declined from about 6.4 children for every woman of reproductive age in 1905 to about 5 during the 1970-75 period to about 2.5 by the end of the twentieth century.¹ In most of the developed economies this transition occurred at the beginning of the nineteenth century.² Understanding the economic and demographic forces behind such structural transformation of the economy has become the focus of a number of recent studies and one of the most interesting topics in the economic growth literature.

As set out by Galor and Weil (2000) and Galor (2005), the evolution of demographic and economic variables and their interrelationships through time can be described by a process that involves three stages: the Malthusian regime, the post-Malthusian period, and the demographic transition to sustainable growth. As Galor (2005) observed, technological progress and population growth were insignificant in comparison with modern standards during the Malthusian period, since the expansion of the agricultural frontier and improvements in technology did not increase per capita income in the long run, but did have an impact on population size. In the post-Malthusian regime, the process of industrialization began and technological progress increased, and this caused increases in per capita income. Nevertheless, the positive effect of per capita income on population growth persisted during the post-Malthusian regime, and the incremental increase in income generated by technological progress was in part offset by increases in population. Finally, in the third stage, during the demographic transition, increases in income were no longer accompanied by an increase of population, with the result that technical progress and industrialization, and their interaction with human capital accumulation, led to sustained growth of per capita income. The increased demand for educated workers as a result of technological progress and the process of industrialization, increased the returns to human capital accumulation

¹See Florez (2000) for an analysis of the sociodemographic transformations in Colombia during the twentieth century.

²See Galor (2005).

which, along with lower levels of mortality and higher levels of life expectancy, led to a reduction in the number of desired offspring (e.g. a decrease in the rate of population growth), and an increase in investment in their education.

During recent years, the economic growth literature has placed a lot of emphasis in explaining the endogenous transition in a unified theoretical model that is capable of describing the process of development and growth in nations through time³. In a seminal contribution, Galor and Weil (2000) developed a unified endogenous growth model to explain the evolution of population, technology and output and their interrelationship over different epochs of human history, with the endogenous reduction in fertility rates playing a key role in the rise of income per capita above the subsistence level. In this model, the reduced fertility rate is a response to technological progress, which raises both the demand for human capital and its rate of return, thus inducing parents to have fewer children with higher levels of human capital. Other theoretical studies on unified growth models include Galor and Moav (2002), Hansen and Prescott (2002), Galor and Mountford (2008), Doepke (2004), Galor (2005), Fernandez-Villaverde (2001), Soares (2005), Cervellati and Sunde (2007), and Falcao and Soares (2007).

Despite the recent surge in theoretical models aimed at explaining the transition from a stage of stagnation to a stage of sustained economic growth and the demographic transition, few studies have empirically estimated the interaction between the evolution of demographic and economic variables within a unified growth framework. The main problem for such an empirical analysis is the intrinsically endogenous character of the variables involved in the explanation. One way to solve this difficulty is to use modern time series econometric techniques, such as vector autoregressive models (VAR). In this line of work, Nicolini (2007) uses a multivariate setting to estimate a VAR system for the British economy that includes annual series for fertility and mortality rates and for real wages from 1541 to 1841. This allows him to test the Malthusian hypothesis, where an exogenous increase in the real wage should be followed by an increase in fertility rates (the so-called preventive check) and a decrease in mortality rates (the so-called positive check). The estimations were made for the whole sample and for one hundred year intervals (1541-1640, 1641-1740 and 1741-1840). Impulse response functions (IRF) show that positive checks disappeared before

³See Broadberry (2007) for a review of recent developments in the theory of very long run growth.

the middle of the seventeenth century, whereas the preventive check had vanished by the mid-eighteenth century. In short, Nicolini's results suggest that the two most important mechanisms required to restore the Malthusian equilibrium disappeared by the middle of the eighteenth century in England. Therefore, Nicolini (2007) concluded that England began to move out of the Malthusian dynamics well before the Industrial Revolution.⁴

Similarly, Craft and Mills (forthcoming) estimate a VAR system⁵ that includes crude birth and death rates and real wages in order to provide quantitative evidence on the mechanisms of the so-called Malthusian regime in pre-industrial England.⁶ Unlike Nicolini (2007), who uses the real wage series of Phelps et al. published in 1956 and the real wages of workers in London re-estimated by Allen in 2001, Craft and Mills use the latest available historical data for real wages calculated by Clark in 2005 and covering the period 1263-1913. Their results share some main stylized facts with Galor and Weil's (2000) unified growth theory. For instance, they found that in the Malthusian regime's real wages showed no trend up until the onset of the Industrial Revolution. After the Industrial Revolution, wages take-off. In addition, fast technological progress occurred at the beginning of the nineteenth century in the so-called post-Malthusian period. Nevertheless, they found that the British economy had departed far from the Malthusian regime by the middle of the seventeenth century, earlier than the unified growth model would have predicted. In addition, and in contrast to this model, the authors did not find any tendency for technological progress to accelerate as population rose, a key element that helps the economy move away from the Malthusian trap.⁷

Other empirical papers, also using time series techniques, have concentrated on the demographic transition process during the second half of the twentieth century. Hon-

⁴Previously, Nicolini (2003) included the crude marriage rate in the VAR system, in addition to mortality, fertility and real wages.

⁵To compute the dynamic responses of variables to shocks to one of the variables, Craft and Mills (forthcoming) use the generalized impulse response functions.

⁶Craft and Mills (forthcoming) perform a series of tests to find a structural break point of the real wage series. They find a clear break of trend at 1800; before this date real wages were stationary. Therefore, the empirical analysis focused on the pre-1800 period. However, they estimate VARs, for structural shifts throughout the period up to 1800 and accumulated 25 years of generalized impulse response functions.

⁷Other papers that conduct quantitative analysis for the demographic transition theory are, for instance Bar and Leukhina (2008) for England and Greenwood and Seshardi (2002) for the United States. Instead of using time series techniques, these studies calibrate the models numerically.

droyiannis and Papapetrou (2002) analyze the relationship between the fertility and infant mortality rates, real wages, and real per capita output in Greece during the period 1960-1996, using vector error correction models, generalized variance decomposition analysis, and generalized impulse response functions (GIRF). The main result indicates that fertility changes are endogenous to infant mortality, real wages, and real per capita output. In a similar way, Climent and Meneu (2004) test the relationship between the same demographic and economic variables for Spain during the period 1960-2000. Their results suggest the existence of a long-run relationship between the four variables. In addition, the authors find that fertility rates and per capita income are clearly endogenous. Specifically, fertility responds to shocks in income and real wages; real per capita GDP is affected by real wages, and infant mortality does not cause fertility.

In most of the available literature, empirical research on the co-evolution of demographic and economic variables has focused on developed economies. To the best of our knowledge, the only exception is Delajara and Nicolini (2000), who study short-run Malthusian patterns in two Argentine regions with different levels of development (Buenos Aires and Tucuman) for the period 1914-1970. Using a VAR model, which includes crude birth rate, crude death rate, crude marriage rate, real wages, and real per capita income, the authors find significant differences between the regions. In Buenos Aires, Malthusian preventive checks were common during the period under analysis whereas positive checks were absent. In contrast, in Tucuman preventive checks were weaker while positive checks were stronger. The authors conclude that the interactions between demographic and economic variables in Tucuman resemble that of a pre-industrial economy, while in Buenos Aires those interactions are similar to those of a modern economy.

This paper presents an economic framework for understanding the main forces behind the demographic transition in Colombia, and the take-off from a stage of stagnation that characterized the Colombian economy up until the first half of the twentieth century to a state of sustained economic growth.

We use annual data for Colombia between 1905 and 2005 to test the main predictions of the model with time series analysis, finding empirical support in their favor. In the Malthusian regime a positive shock in per capita income led to increases in the growth rate of population and has no effect on human capital accumulation, as expected, while increases in real GDP per capita during the modern growth regime do not led to considerable

increments in population but, instead, led to increases in human capital accumulation.

The rest of the paper is organized as follows. Section 2 presents the model; section 3 describes some stylized facts of the Colombian demographic transition. Section 4 reports and discusses the econometric results, and section 5 concludes.

2 The Model

In this section we use Doepke's (2006) simplified version of Galor and Weil's (2000) model to explain the main forces behind the Malthusian and modern growth regimes, and make special emphasis on the model's predictions regarding the relationship between the endogenous variables of the model under these different regimes. Namely, the emphasis in this section will be on the relationship between income, the rate of growth of population, fertility rates, and human capital investment during the different growth regimes. Thus, we will present the model in the simplest, most intuitive possible way without giving special emphasis to the details of the underlying dynamical system that governs the evolution over time of the endogenous variables of the model. In other words, in this section our intention is not to fully characterize and close the model but, rather, to highlight the crucial forces and stages behind the demographic transition and the transition from a stage of stagnation to a stage of sustained economic growth.⁸ In the empirical exercise we will also account for other variables that can potentially affect some elements of the model such as mortality rates. The emphasis of this section on the predictions that are derived from the model should help us motivate the empirical exercise that will be carried out in section 4.

2.1 Preferences

Individuals derive utility from consumption and a quality-adjusted measure of the number of offspring they have. More precisely, individuals' preferences are given by:

$$u(c_t, n_t, h_{t+1}) = (1 - \beta) \ln c_t + \beta [\ln n_t + \gamma \ln h_{t+1}], \quad \text{with } \beta, \gamma \in (0, 1), \quad (1)$$

⁸The reader is referred to Galor and Weil (2000) and Lucas (2002) for a full characterization of the model and the evolution of the dynamical system.

where c denotes consumption, n the number of offspring, and h the human capital of each offspring, the latter being a measure of the quality of children.

Furthermore, the time cost of raising a child with no education is ϕ units of time, and the time cost of providing the child with e units of education is equal to e . In other words the model assumes that there is a one-to-one transformation of time invested in children's education and the level of education that they achieve.⁹

Individual's are endowed with one unit of time that they have to allocate between labor force participation and child rearing (in both the quantity and quality dimensions, should they decide to invest in their children's education). Summing up the costs of child rearing, the individual's budget constraint will be given by:

$$c_t = [1 - (\phi_t + e_t)n_t]w_th_t \quad (2)$$

The budget constraint in equation 2 says that individual's consumption is equal to individual's income, which, in turn, is given by the market wage per unit of human capital, w_t , times the individual's endowment of human capital, h_t , times the amount of time that the individual has left after investing in child rearing, $1 - (\phi_t + e_t)n_t$.

Parental time investment in the education of children is transformed into human capital for their children, h_{t+1} , according to the following human capital production technology:

$$h_{t+1} = 1 + \mu h_t e_t, \quad (3)$$

where $\mu > 0$ is a parameter that captures the efficiency of parental time investment in the formation of children's human capital. Note that the human capital production function is such that children's human capital is increasing in their parents' level of human capital and on parental time investment in their education. Also, parental education and parental time investment are complementary in the production of the children's human capital. Equation 3 also makes a crucial assumption: if parents do not invest in their children's education, children would still have one unit of human capital.¹⁰ This assumption reflects the fact that, even if parents do not invest in their offspring's education, individuals have

⁹This is a simplifying assumption that can easily be relaxed. The important point is that children's education is a positive and concave function of parental time investment in their offspring's education.

¹⁰This assumption guarantees that, under some conditions, the optimal level of investment in children education is in a corner solution with $e_t = 0$.

a given endowment of abilities (human capital) that allows them to perform certain basic tasks.

Finally, another crucial and perhaps realistic assumption of the model (specially for the early stage of economic development) is that individuals face a subsistence consumption constraint. Formally:

$$c_t \geq \underline{c}, \quad (4)$$

where \underline{c} denotes the minimum level of consumption necessary for subsistence.

2.2 Individual's problem

The problem faced by the representative individual is to choose non-negative values of c_t , n_t , and e_t , in order to solve the following maximization problem:

$$\begin{aligned} & \max_{\{c_t, n_t, e_t\}} u(c_t, n_t, h_{t+1}) \\ \text{subject to} & \quad : \quad 2, 3, 4, \end{aligned} \quad (5)$$

Two types of solutions emerge from the individual's optimization problem in equation 5, a corner solution and an interior solution. As we shall see, each of these two possible solutions characterize the Malthusian epoch and the modern growth regime, respectively.

Explicitly modelling the production side, the determination of wages, and the process that governs technological progress is beyond the scope of this paper. We will simply assume that technological progress takes place and, as a result, wages raise over time. Furthermore, one can think that technological progress is function of the size of population (as in Kremer, 1993) or a function of the per capital level of education and the size of the population (as in Galor and Weil, 2000). For the sake of our objective in this section, the important point to keep in mind is that wages raise over time as a result of technological progress, which increases the underlying returns to parental time investment in the human capital of their children. Other factors such as increases in life expectancy or technological progress might also raise the incentives for parents to invest in the human capital of their offspring by increasing the parameter μ in equation 3.

2.3 The Malthusian epoch

Let us first start with the corner solution of the model. If the income level of the individual, $w_t h_t$, is lower than a threshold level that makes the subsistence constraint binding, that is, if $w_t h_t \leq \frac{\underline{c}}{1-\beta}$, then the solution to the individual's maximization problem is given by:

$$c_t^* = \underline{c} = [1 - \phi n_t^*] w_t h_t \Leftrightarrow n_t^* = \frac{1}{\phi_t^*} \left(1 - \frac{\underline{c}}{w_t h_t} \right), \text{ and,} \quad (6)$$

$$e_t^* = 0. \quad (7)$$

Notice that, because wages are increasing over time as a result of technological progress and the solution says that parents do not invest time and effort in the education of their children, implies that h_t will be equal to 1 (individuals only have the skills to perform very basic tasks) and, thus, the subsistence constraint will be binding if the wage rate is sufficiently low. More precisely, the subsistence constraint is binding for $w_t \leq \underline{w} = \frac{\underline{c}}{1-\beta}$. According to the solution in 6, in the early epoch of economic development income is low, consumption remains at a subsistence level, there is no investment in the quality of children (e.g. in their education) and the relationship between income, $w_t h_t$, and population growth which in turns dilutes the initial increase in income. Furthermore, during the Malthusian epoch, there is no relation between income and human capital investment, as in this early epoch of economic development there is no investment in the quality of children (e.g. in human capital). The mechanism underlying this solution is purely a Malthusian one. That is, any increase in income, due to the fact that there is (slow) technological progress, will translate into a larger population size and not into higher standards of living, as captured by the income level. Individuals in this early epoch do not invest in human capital and, thus, there is no relationship between increases in income (due to technological progress) and increases in the rates of investment in human capital accumulation.

2.4 The modern growth regime

As technological progress continues to take place as a result of increases in the size of the population, the economy will reach a point where wages are sufficiently high and the subsistence consumption constraint becomes no longer binding. This is a so-called “interior”

solution that is fully characterized by the following equations (derived from the first order conditions associated with the problem in equation 5):

$$\begin{aligned} c_t^{**} &= (1 - \beta)w_t h_t, \\ n_t^{**} &= \frac{\beta}{\phi + e_t^{**}}, \text{ and,} \\ e_t^{**} &= \frac{1}{1 - \gamma} \left(\gamma\phi - \frac{1}{\mu h_t} \right). \end{aligned} \tag{8}$$

The modern growth regime arises at a point where income is sufficiently high (that is, when $w_t > \frac{\underline{c}}{1 - \beta}$) and, as a result, the subsistence consumption constraint is no longer binding. At this stage of the development process, increases in income, resulting from an underlying process of technological progress, do translate in to higher standards of living, higher investment in education, and lower population growth. The solution for n_t under this regime captures the quantity-quality trade-off. That is, the number of children that parents choose to have is negatively associated with the optimal level of investment in education that they choose to give to each child.

During this modern epoch of the development process, increases in income no longer translate into a larger population size and as a result standards of living rise and the economy transits from a stage of stagnation characterized by the Malthusian forces described before into a stage of sustained economic growth. Increases in wages (due to the underlying process of technological progress) increase the returns to human capital accumulation and parents optimally substitute the quantity of children for greater quality - that is, for more time investment in their education. As a result, the rate of growth of population decreases as income increases and, as a result, the economy takes-off from a stage of stagnation to a stage of sustained economic growth.

3 The Stylized facts of the Colombian demographic transition

In Colombia, we have identified the two stages: the Malthusian regime and the sustained economic growth regime. These have characterized the interrelationships among demographic and economic variables in Colombia as follows:

The Malthusian regime

According to the available data, the nineteenth century and the first half of the twentieth century in Colombia can be characterized as a Malthusian period, with low levels of per capita income, low economic and population growth, very high mortality and fertility rates and very low life expectancy and human capital accumulation rates, in the context of a rural and agrarian economic structure.¹¹ In general, the period is characterized by poor economic and living conditions.

Colombian economic growth was very slow during the nineteenth century. According to Kalmanovitz (2008), during the nineteenth century, per capita income grew only at 0.1 percent per year. During the first half of that century per capita income remained stagnant with almost zero growth, grew at an annual rate of 0.5 percent during the period 1851-86 (explained mainly by an increase in exports) but decreased between 1887 and 1905 because of civil wars and macroeconomic disequilibria that occurred at the end of the century.¹² The country was also very poor. Kalmanovitz (2008) estimates that in 1800 the level of Colombian per capita income was 69 percent of Mexico' per capita income and only 39 percent of that of the United States. Fifty years later, the country was even poorer, and Colombian per capita income was 20 percent of that in the United States; by 1913 it was only 13 percent. In addition, Urrutia (forthcoming) shows that urban real wages did not increase during the nineteenth century. In other words, there was no trend of long-run economic growth in real wages during this period in Colombia, which suggests that per capita urban income, reflecting an economy with few changes, did not increase during this time period.

Regarding population, a recent study by Florez and Romero (forthcoming) shows the evolution of the basic demographic parameters of the Colombian population during the nineteenth century. They found that population was stable throughout the century, with high but decreasing fertility and mortality rates. The annual average rate of growth was almost constant during the first 70 years of the nineteenth century, approximately 1.6 percent on average. Then the rate of population growth started to increase and reached

¹¹According to the 1870 Colombia census, 54% of the working population was employed in agriculture, cattle-raising and fishing.

¹²The civil war at the end of the century and the financing of the fiscal deficit with money emission were translated into a macroeconomic disequilibrium.

approximately 1.8 percent by the end of the century. This increment is associated with improvements in public health, the expansions of the agricultural frontier, and the settlements in the Antioquia and Cauca regions. These rates appear high for a pre-industrial economy. For instance, during the seventeenth century the average population growth rate in England was approximately 0.3 percent per year, and during the first half of the eighteenth century about 0.4 percent.¹³ However, according to the authors, the population growth rate in Colombia during 1820-70 was smaller than that in Argentina (2.6%) and Brazil (2%), although higher than that for Peru (1.1%) or Mexico (0.7%).¹⁴

Florez and Romero (forthcoming) calculate that mortality and birth rates were almost constant between 1800 and 1870. However, both rates subsequently started to decline, with a larger decline in the mortality rates than in the birth rates. In particular, the mortality rate decreased from 40 deaths per one thousand people during 1800-70 to 29.5 by the end of the century. The birth rate declined from 56.6 births per thousand to 47.7 in the same period. At the same time, fertility rates were very high: 8.5 children per woman of reproductive age at the beginning of the century (1800-25), and 7.4 children in 1898. Such high rates were essential to preserve population growth, given the observed high mortality rates.

Given the poor conditions in the standards of living, health, nutrition, and the low levels of income, the child mortality rate was high, although decreasing through the century. Florez and Romero (forthcoming) estimate that during the first part of the nineteenth century, the child mortality rate was 297 deaths of children younger than one year old per thousand births, but had fallen to 250 by the end of the century. Among the factors behind the decline in the mortality rate were the improvements in nutrition and sanitary conditions.¹⁵ Life expectancy at birth was also very low in nineteenth-century Colombia. At the beginning of the century it was 26.5 years on average, and it rose to 31 years by the end of the century.

In terms of human capital, Colombia was one of the world's most backward countries in education during the nineteenth century. The ratio of primary school students to total

¹³See Madison (2000) and Bar and Leukhina (2008).

¹⁴Florez and Romero (forthcoming) made this comparison with information on Latin American population growth calculated by Coastworth in 1998.

¹⁵See Florez and Romero (forthcoming) and Meisel and Vega (2007).

population was considerably smaller in Colombia than in developed countries, and even less than the Latin America average (graph 1). For instance, by the mid-nineteenth century in the United States, the number of primary school students relative to total population was nearly 20 percent. It was more than 10 percent in Holland and the United Kingdom, nearly 10 percent in France, and more than 5 percent in Spain. In Colombia this indicator never reached more than 3 percent, and the gap between Colombia and the developed countries increased throughout the century. In addition, as Ramirez and Salazar (forthcoming) show, education in Colombia was not only backward in terms of international patterns but also presented a very slow expansion; the ratio between the number of children enrolled in primary education and total population barely grew from 1.5 percent in 1837 to 2.6 percent in 1898. As a result, educational advances in Colombia were marginal during the course of the nineteenth century. The failure to achieve a mass coverage in primary education in Colombia during that century was attributable to the absence of a suitable structure of incentives for its expansion, given the economic, political, and social organization that prevailed in the country. In short, nineteenth-century Colombia displayed patterns of a pre-industrial economy that fit the description of the Malthusian phase of development relatively well.

Graph 1 Here

Per capita income and population started to increase around 1870, although very slowly. Some demographic indicators also began to improve. However, at the end of the century the country faced a bloody civil war (the Thousand Days War, 1899-1902), that led to a serious crisis in the external and financial sectors, and high levels of inflation and public debt. In addition, infrastructure was dismantled. Therefore, the little progress that Colombia had achieved during the last decades of the nineteenth century was interrupted by the war, and the country finished the century with conditions similar to those at the start of the century.

After the war, a policy of economic reconstruction was adopted and a series of laws were passed to regulate and organize the country's public administration. The reconstruction policies included large public investments in public works, promotion of agricultural exports, especially coffee, and an active industrialization program. The economy began to grow at low rates at the beginning of the twentieth century, and both population and per capita income increased (graphs 2 and 3). The average real per capita GDP growth was 2.7 percent per year during 1905-50, and population grew at an annual average rate close

to 2.3 percent, explained by a high fertility rate and the decline in the mortality rate that occurred during the 1920s. Also, the real manufacturing wages index grew during these years (graph 4).

Graphs 2, 3 and 4 here

The standard of living began to improve with higher income, better nutrition and sanitation, among other factors.¹⁶ The mortality rate showed a sustained decline (graph 5). For instance, the child mortality rate fell from 186.5 deaths per thousand births in 1905 to 125 by the end of the 1940s. Life expectancy at birth also improved, from 39.5 years in 1905 to 48.8 years in 1950. At the same time, the fertility rate increased, as well as that for education (graphs 6 and 7). Fertility rates rose from 6.4 children per woman of childbearing age at the beginning of the twentieth century to almost 6.8 by the end of the 1940s. Although education began to expand, especially at the primary level, the expansion of primary and secondary education in Colombia during the first half of the twentieth century was very slow. With reconstruction policies at the beginning of the century, that included the 1903 Law 39 mandating the organization and regulation of education, the ratio of students enrolled in primary school to total population increased from 3.5 percent in 1900 to 4.8 percent in 1908, but over the following years this ratio rose only to about 6.7 percent by 1950, which suggests only moderate progress in education during the first half of the twentieth century. The little progress achieved in primary enrollment kept the gross enrollment rate in primary education almost constant between 1938 and 1950, averaging only 34 percent during these years.¹⁷

Graphs 5, 6 and 7 here

The modern growth regime

Since the 1950s, Colombia has experienced rapid and sustained economic growth and significant transformations in its economic and demographic structure. In particular, the economic structure has moved from agricultural to industrial, communication and services activities. In the 1950s, the government started an ambitious program of import substitutions to promote the country's industrialization, which encouraged a considerable increase in rural migration to the cities and contributed to the increase of urbanization.¹⁸ As a

¹⁶See Florez (2000) and Meisel and Vega (2007).

¹⁷See Ramirez and Tellez (2007).

¹⁸According to Urrutia and Posada (2007) the rural migration to the cities during the 1950s and 1960s

result, the urbanization rate rose from 39 percent in 1951 to 50 percent in 1962 and 75 percent in 2000 (graph 8). The migration from rural to urban areas implied a labor force movement from low productivity activities such as agriculture to higher productivity areas like manufacturing and services.¹⁹

Graph 8 here

The economic transformations that have occurred since the 1950s increased the demand for more educated workers and induced investment in human capital.²⁰ These factors, in conjunction with increased fiscal revenue and favorable economic conditions, allowed education to take off in Colombia. According to Ramirez and Tellez (2007), from 1950 until the mid-1970s, the education indicators for number of students, teachers, and schools grew at an unprecedented rate in both primary and secondary education. In fact, during these years the number of students enrolled in primary and secondary grew at a higher rate than population. For instance, the average annual rate of growth in primary enrollment during the 1950s was 7.7 percent, and for the 1960s it was 6.9 percent; secondary enrollment grew to 12.4 percent and 13 percent for the decades, respectively (graph 7).²¹

Demographic transformations in Colombia were remarkable during the second half of the twentieth century. In the 1950s the rate of population growth continued to be high (the average annual rate of growth was close to 3%) because of the still high fertility rates and declining mortality rates (graph 5).²² However, by the mid-1960s the fertility rate began to decrease significantly as a consequence of the decline in the child mortality rate, birth control planning, and the high opportunity cost for women with a greater participation in the labor force, among other factors.²³ As graphs 7 and 9 show, the decline in fertility was preceded by an increase in the human capital investment and its rate of returns. This decline in fertility and a continuing decline in the mortality rate, led to a reduction in

was mainly motivated by the rural-urban wage differential.

¹⁹See Urrutia and Posada (2007).

²⁰According to Echavarria (1999), since the 1930s the industrialization process has brought a substantial increase in the demand for a skilled labor force since the earlier experience with unskilled labor was unfruitful.

²¹For details of the evolution of the education in Colombia during the twentieth century, see Ramirez and Tellez (2007).

²²Florez (2000) characterized this period as a demographic explosion in Colombia, with average rate of population growth more than two times higher than that in Europe during the transition.

²³For details of this transformation, see Florez (2000).

the rate of population growth, which was close to 1.8 percent at the end of the twentieth century (graph 2). In addition, the decline in the mortality rate reflected an increase in life expectancy at birth, which also had preceded the decline in fertility and which improved from 49 years in 1950 to 63 years in 1975 and 72 years in 2000.

Graph 9 here

4 Estimations and results

We use modern time series techniques to test the main predictions of the unified growth model. Because of data availability, our empirical analysis is concentrated on the 1905-2005 period, which includes the end of the Malthusian regime (1905-45) and the demographic transition period (1955-2005).²⁴

To estimate empirically the interaction between the evolution of the demographic and economic variables, we use cointegration techniques, vector autoregressions (VAR), and vector error correction (VEC) models, which serve to identify long-run relationships, in a multivariate system with non-stationary variables. This allows us to analyze the dynamic properties of the system by estimating the impulse response functions (IRF) of each variable to shocks in the other variables.²⁵ Also, using these techniques, we can distinguish between exogenous and endogenous variables, an issue that is important given the complex interactions among these variables.

In both periods, we estimate two systems. The first one (Model 1) include annual data for population (P), real per capita gross domestic product (RPGDP) and students enrolled in secondary education as a proxy for human capital (HC). The second system (Model 2) includes series of fertility (FR), child mortality (MR) rates, RPGDP and HC²⁶ (Graphs 2,

²⁴We applied recursive cointegration tests to determine structural changes. The results (available upon request) show that the sample can be divided in such periods.

²⁵To check for robustness in the results, we also used Generalized Impulse Response Functions (GIRF), which constructs an orthogonal set of innovations that does not depend on the VAR ordering. In general, the results of the GIRFs (available upon request) are very close to the IRFs with Choleski decomposition. Only in the case of Model 1 in the demographic transition period, the responses of population and human capital to a shock in real per capita income are slightly lower when using GIRFs.

²⁶To check also for robustness in the results, we consider in the systems other variables such as crude rate of birth and primary enrollment rates. The results of the estimation are basically the same.

3, 5 and 7).

4.1 Results for the Malthusian period

Preliminary examination of the stationary properties of the series during this period suggests that all series are integrated of order one, $I(1)$, but their first differences are stationary $I(0)$, according to the Augmented Dickey Fuller (ADF), Philips and Perron (PP), and Kwiatkowski et al. (KPSS) tests. Given that the series in levels are not stationary, we proceed with cointegration tests among the variables, using the Johansen multivariate methodology for cointegration. The first exercise includes population, real per capita GDP, and human capital (Model 1). Table 1 presents the cointegration test results, which suggest a long-run relationship among the variables.²⁷ The trace and λ -max tests indicate again the presence of a unique cointegration vector.

Table 1 here

Table 2 shows the results of some multivariate tests for checking autocorrelation (LM, Portmanteau, and L-B tests) and heterocedasticity (White test). The tests indicate that the system exhibits white noise and no heterocedasticity. In addition, the exclusion, stationarity, and weak exogeneity tests, presented in Table 3, show that no variables are excluded from the cointegration vector; all the variables are integrated of order 1 ($I(1)$), and only human capital is a weak exogenous variable during the period under analysis. The character of weak exogeneity of human capital is not surprising during this period, given its passive role and low levels during the end of the Malthusian regime.

Tables 2 and 3 here

From the VEC model, we estimate the impulse response function (IRF) in which population responds to a positive shock in the real per capita GDP.²⁸ Graph 10 displays these responses through time (annually).²⁹ As observed, an exogenous positive shock in per capita income is followed by an increase in population, as predicted by the model during the Malthusian regime.

²⁷The adequate selected model includes three lags and a deterministic linear trend in the variables levels (drift model). In all models, the lags were chosen according to the AIC and SIC, considering the most parsimonious model which had the best behavior in the residuals.

²⁸The shock of each variable is fixed as Cholesky one standard innovation of that variable.

²⁹The confidence bands in the impulse response functions are obtained by Bootstrapping.

Graph 10 here

Then, we estimate a system (Model 2) including series of fertility rate (FR), child mortality rate (MR), human capital (HC), and real per capita GDP (RPGDP), assuming that MR is exogenous, as Galor and Weil (2000) do. We find a long-run equilibrium relationship among FR, HC and RPGDP with a unique cointegration vector (table 4).

Table 4 here

Tables 5 and 6 present the residual multivariate analysis and the multivariate test for exclusion, stationarity, and weak exogeneity, respectively. The test shows that residuals are well-behaved and do not present either autocorrelation or heteroscedasticity. Human capital appears as a weak exogenous variable during this period.

Graphs 11a and 11b depict the response of the fertility rate and human capital to a shock in real per capita GDP, respectively.³⁰ During this period a positive shock in GDP produces an increment in the fertility rate, but does not have any effect on human capital, yet again, as predicted by the model during the Malthusian equilibrium.

Tables 5 and 6 here and Graphs 11a and b here

4.2 Results for the modern growth period

To empirically test the predictions of the model regarding the demographic transition in Colombia, we perform similar exercises for the 1955-2005 period. We first examine the stationary properties of the variables, P, RPGDP, HC, FR and MR, using the ADF, the PP and the KPSS tests, which indicate that all series are integrated of order one, $I(1)$, while their first differences are $I(0)$. We then proceed to test two models for cointegration following the Johansen methodology. Table 7 presents the cointegration result for the first model, which includes population, real per capita GDP, and human capital. The test suggests that there is not a long-run relationship between the variables.

Table 7 here

Since the series are not cointegrated, we estimate a VAR model in first differences. Table 8 shows the test for the residual multivariate analysis, which indicates that the system exhibits white noise and does not present heteroscedasticity problems.

³⁰In the IRFs, we place fertility first, then human capital and per capita GDP. The results are very similar when we change the ordering of the variables in the VEC.

Table 8 here

Unlike results for the Malthusian regime, the IRFs show that an increase in real per capita GDP does not produce considerable increments in population but causes an important increase in human capital (graphs 12a and 12b). These results fit well the characteristics of a modern growth regime, in which increments in income are not translated into higher rates of population growth but induce higher rate of human capital accumulation.

Graphs 12a and 12b here

In a second model we include fertility rate, human capital, real per capita GDP, and the mortality rate.³¹ The trace and λ -max test indicates the presence of a unique cointegration vector among fertility, human capital and real per capita GDP, which suggests a long-run relationship among these variables (table 9). Tables 10 and 11 show the residuals from the multivariate analysis and the joint tests for exclusion, stationarity, and weak exogeneity. The test for weak exogeneity suggests that the fertility rate is an exogenous variable, while human capital is an endogenous variable, as expected during this period.

Tables 9, 10 and 11 here

Finally, graphs 13a and 13b present the estimated impulse-response functions from the VEC model.³² As observed, an exogenous increase in per capita income produces an important and positive response in human capital, while the response of fertility to this shock is negative and very close to zero. These results are in line with the model predictions for the modern growth regime.

Graphs 13a and 13b here

5 Concluding remarks

While most of the recent contributions in the growth literature have focused on the theoretical underpinnings of the transition from a stage of stagnation to a stage of sustained economic growth, very few studies have tried to bring the unified growth model to the data to test its main implication. Furthermore, the few studies that have tried to test the model's predictions, have done so for now developed economies. By using long time series

³¹As in the previous case, we assume that mortality rate is exogenous.

³²In the IRF we also place fertility first, then human capital and per capita GDP. However, it is worth to mention that the results are very similar when we change the ordering of the variables in the VEC.

that cover the whole demographic transition period in Colombia, we test the main predictions of the unified growth model for a developing economy and find empirical support for the main predictions of Galor and Weil's unified growth model.

In particular, during the Malthusian regime we find that a positive shock in per capita income produces increments in the population but not in education, as expected; during the modern growth regime, increases in real per capita GDP do not produce considerable increments in population, but do have a positive effect on human capital. These results fit well the characteristics of modern growth regime, in which increments in income are not translated into higher rates of population growth but induce higher demand for educated workers during the industrialization process.

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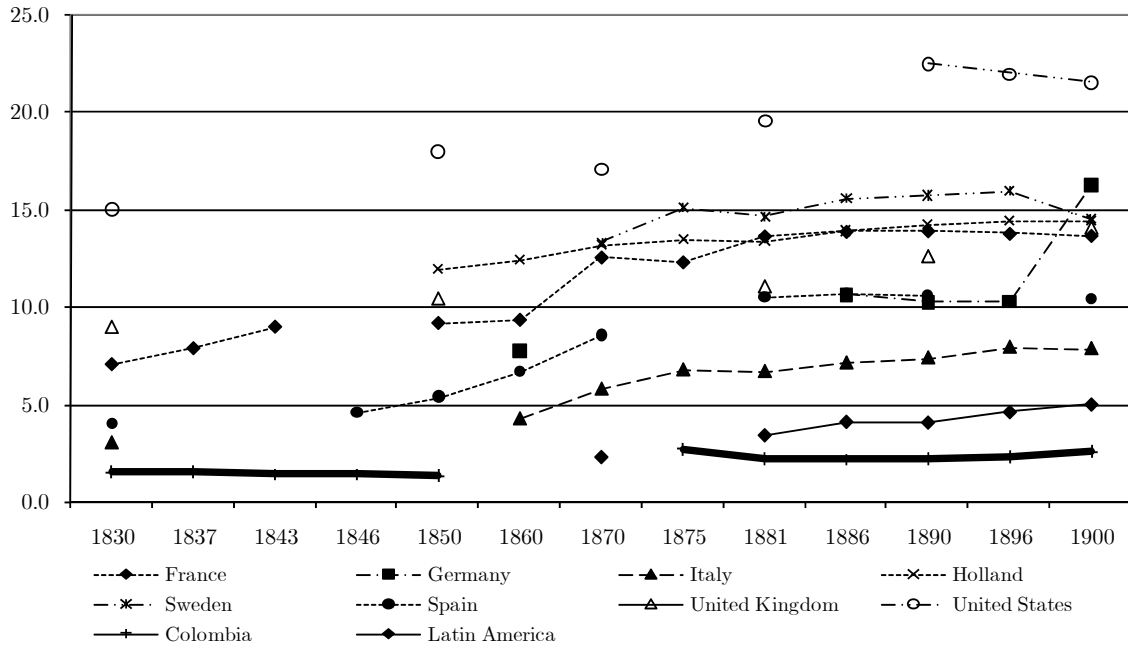
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Graph 1

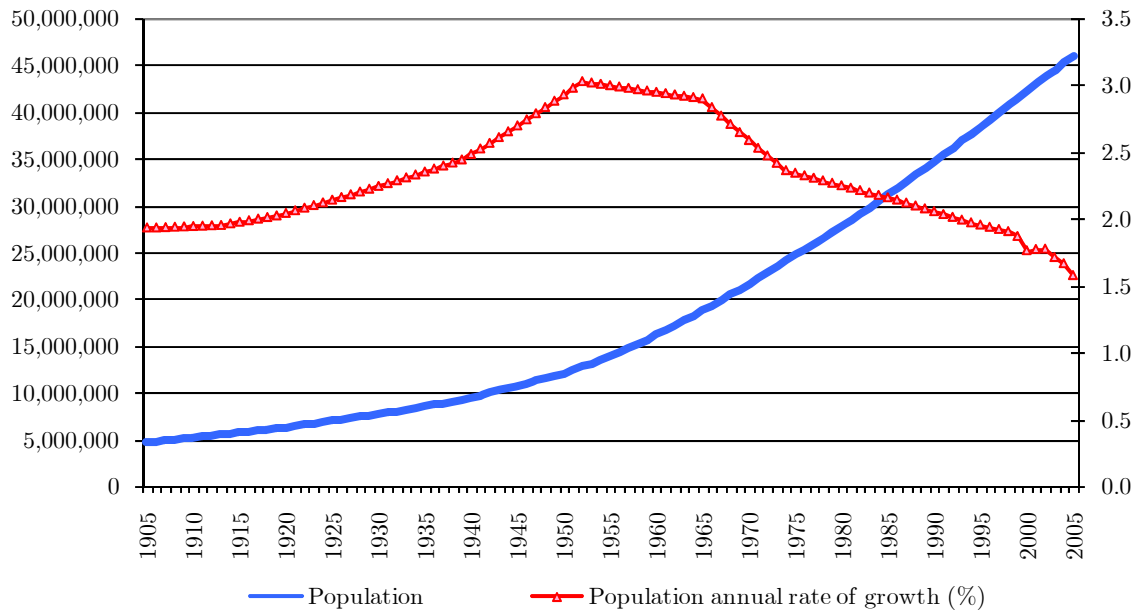
Students in primary education
(percentage of the population)



Source: Ramírez M, T and Salazar, I (forthcoming)

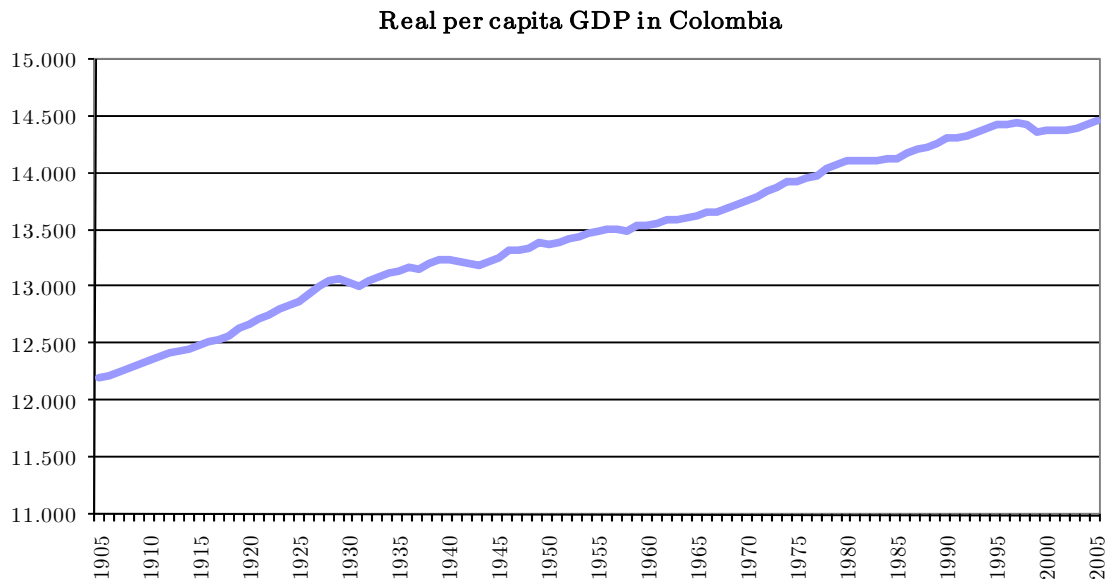
Graph 2

Population in Colombia



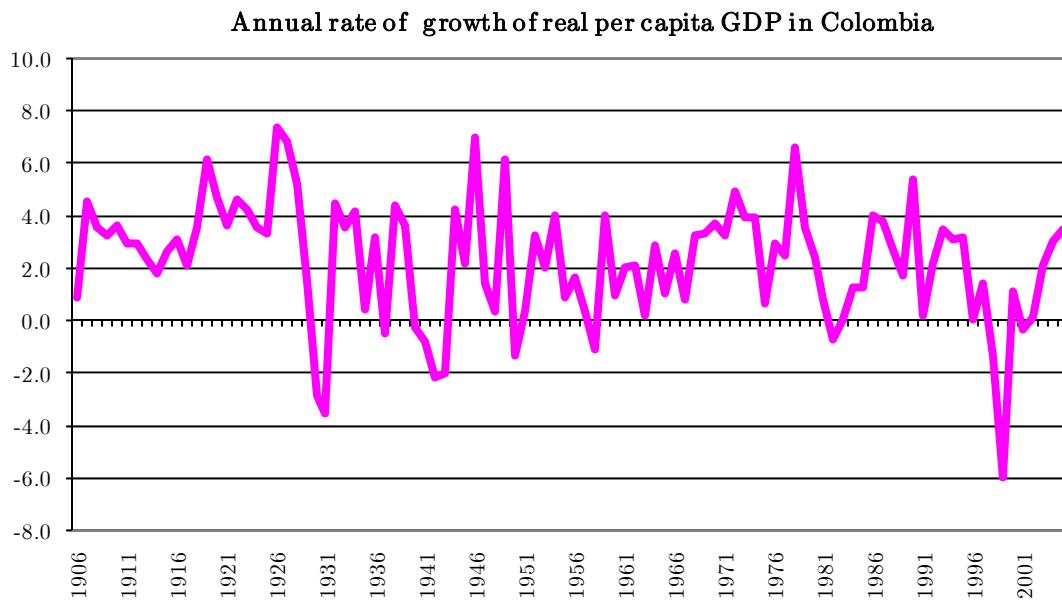
Sources: GRECO (2002) and DANE

Graph 3a



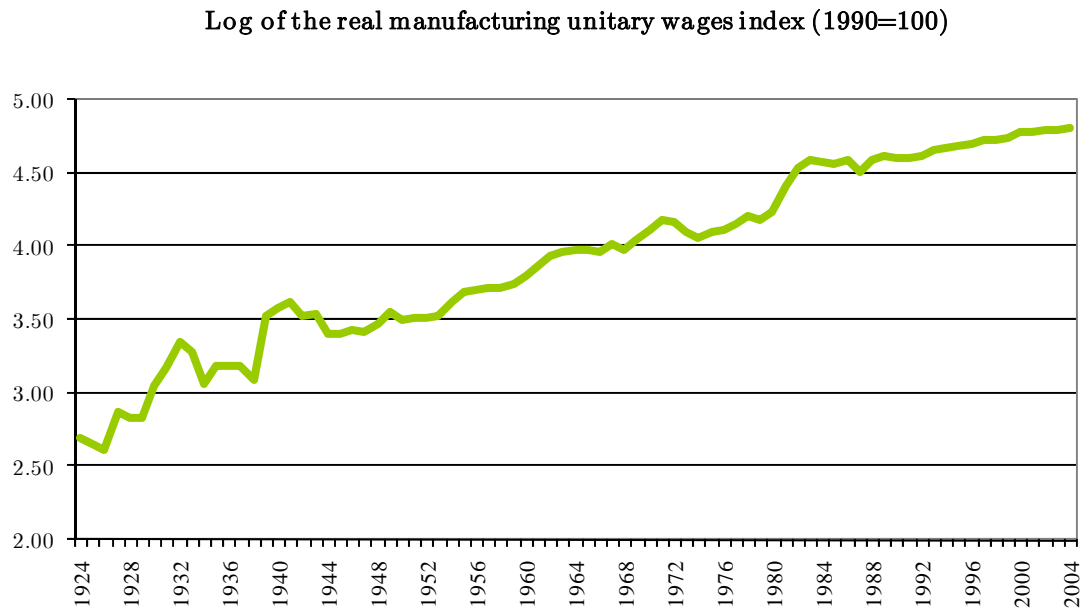
Sources: Florez, C. E (2000), GRECO (2002) and DANE

Graph 3b



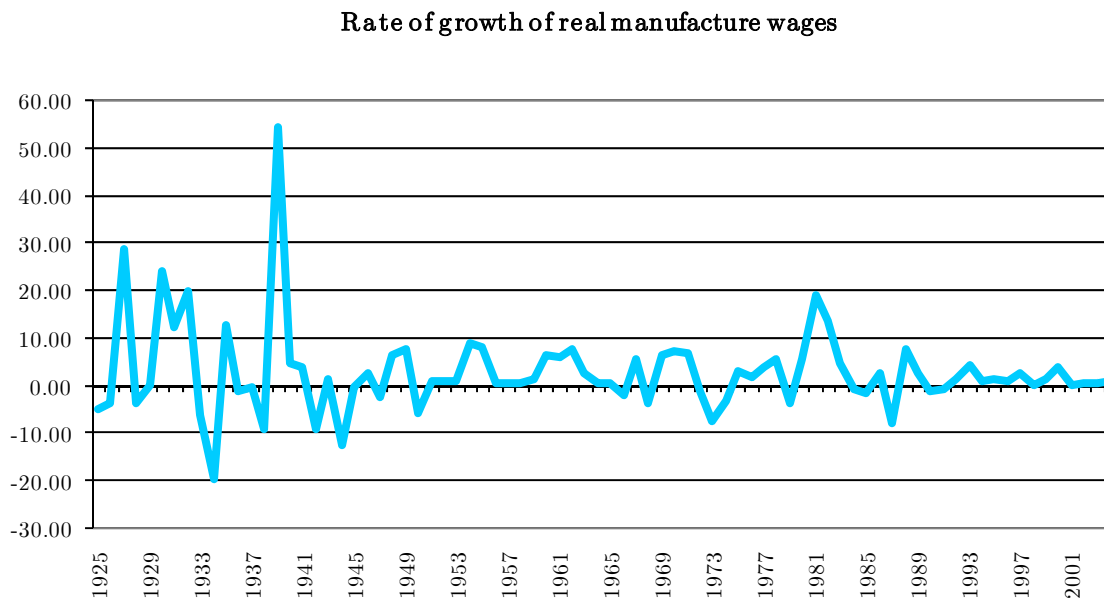
Sources: GRECO (2002) and DANE

Graph 4a



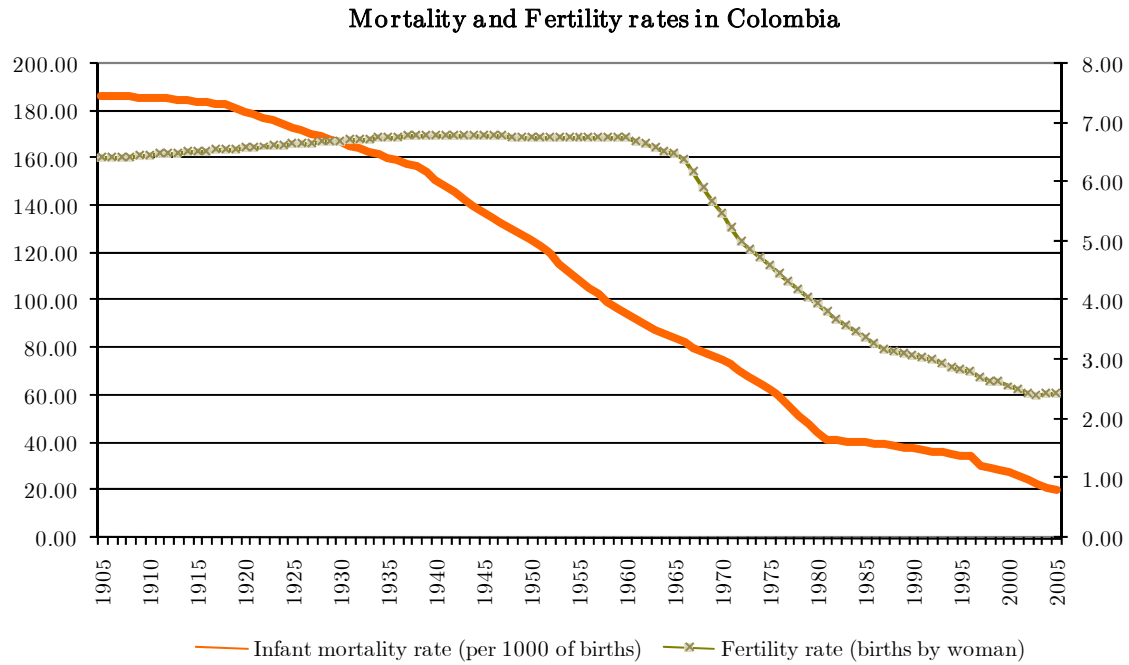
Source: Echavarria, J. J (2007)

Graph 4b



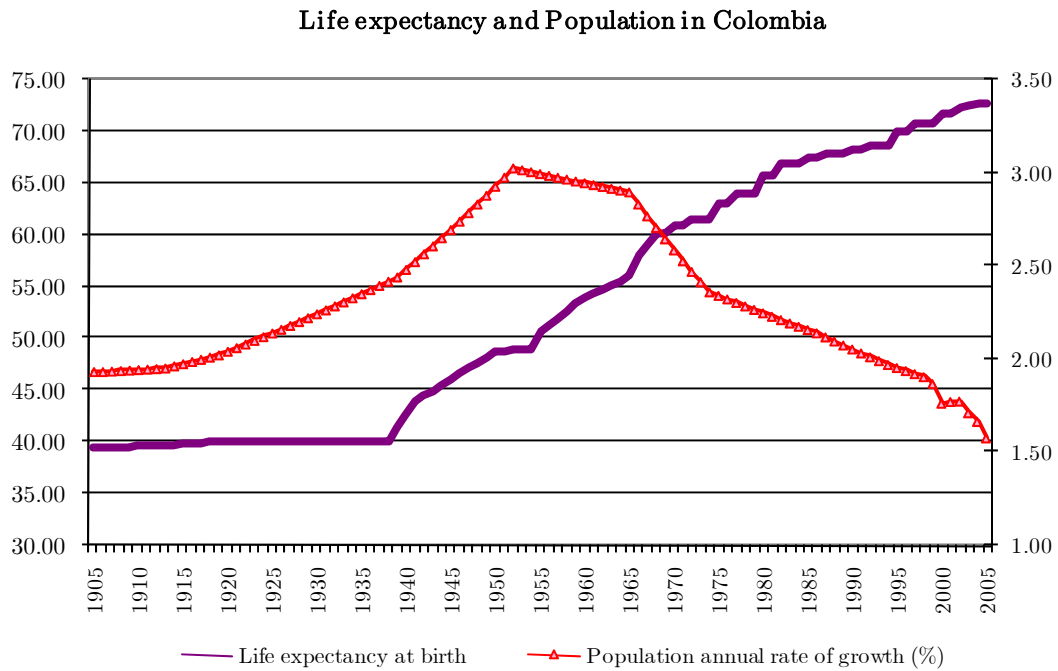
Source: Echavarria, J. J (2007)

Graph 5



Sources: Florez, C. E (2000), GRECO (2002), DANE and author s calculations

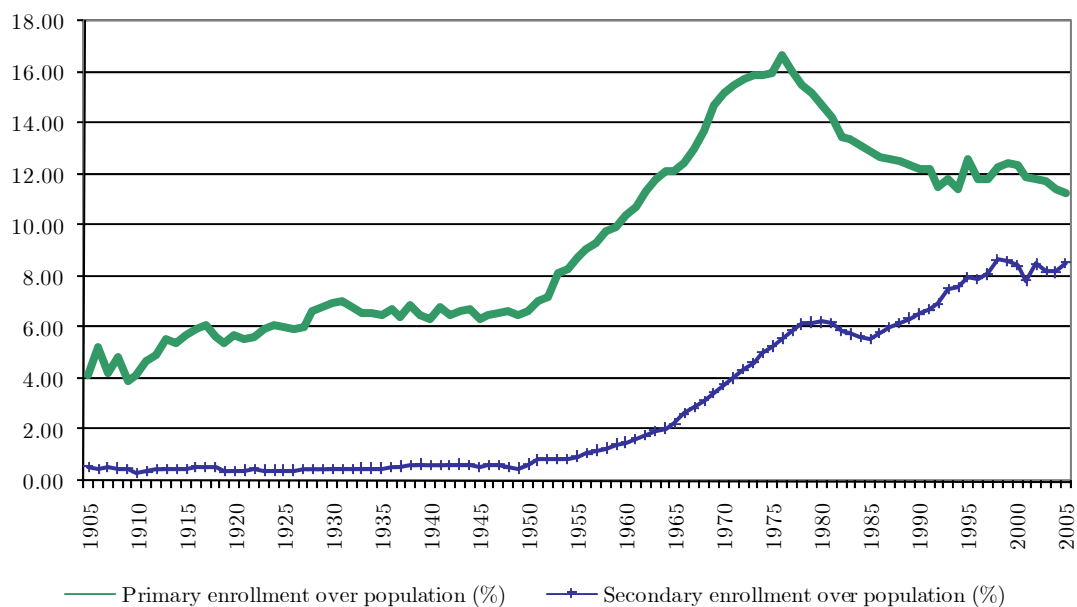
Graph 6



Sources: Florez, C. E (2000), GRECO (2002), DANE and author s calculations

Graph 7

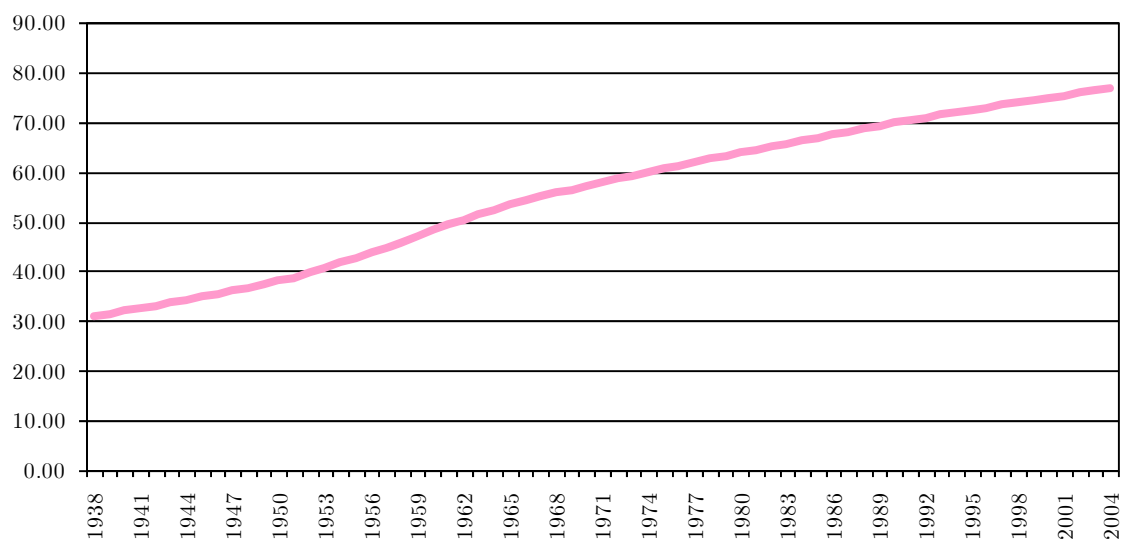
The evolution of Education in Colombia



Source: Ramirez, M.T. and Tellez, J. (2007)

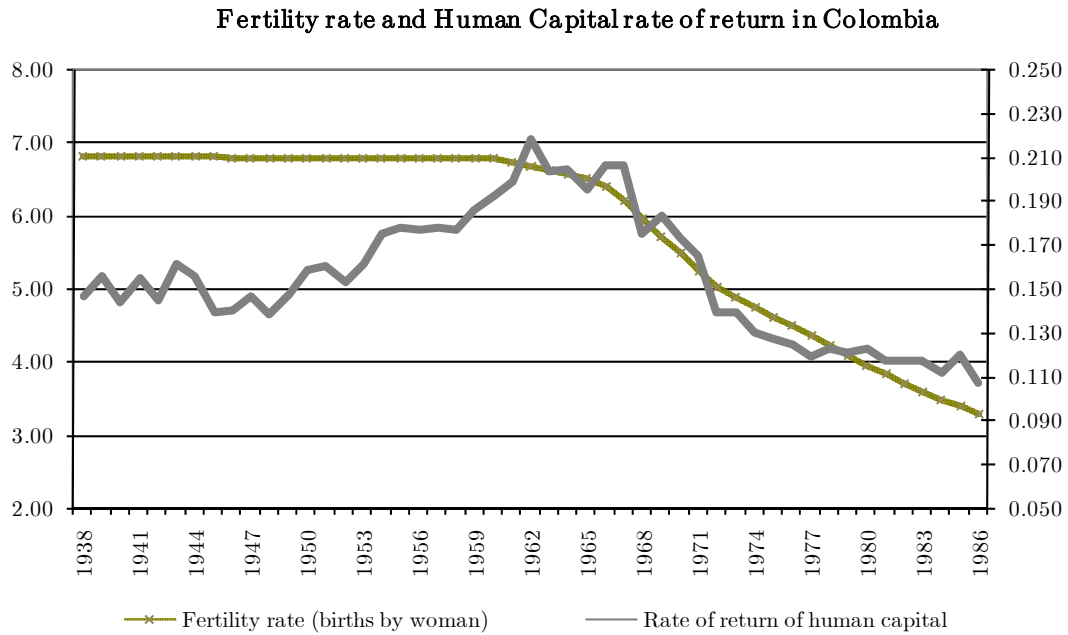
Graph 8

Urbanization rate in Colombia



Sources: Florez, C. E (2000), World Bank CD (2006) and author s calculations

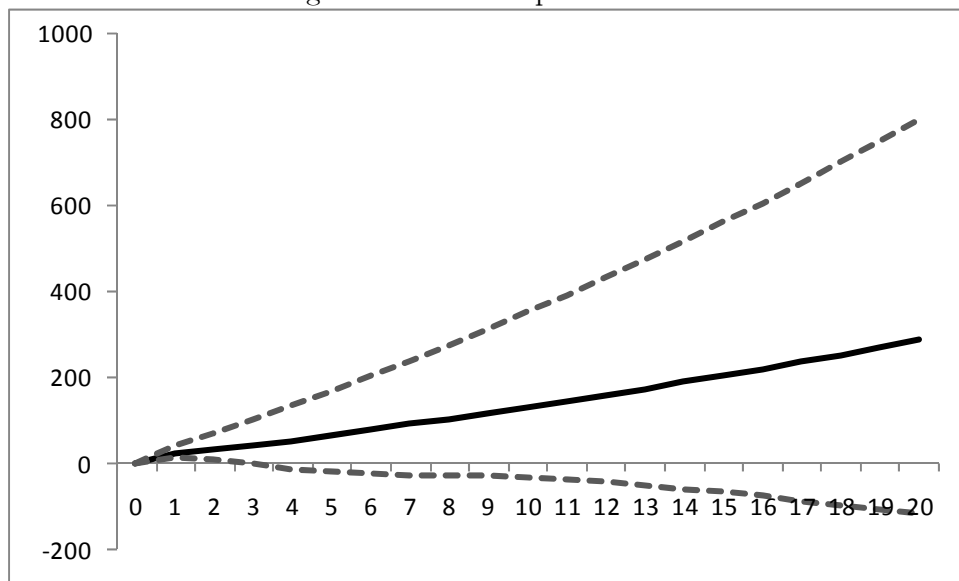
Graph 9



Sources: Florez, C. E (2000), Londoño, J. L. (1995) and author's calculations

Graph 10

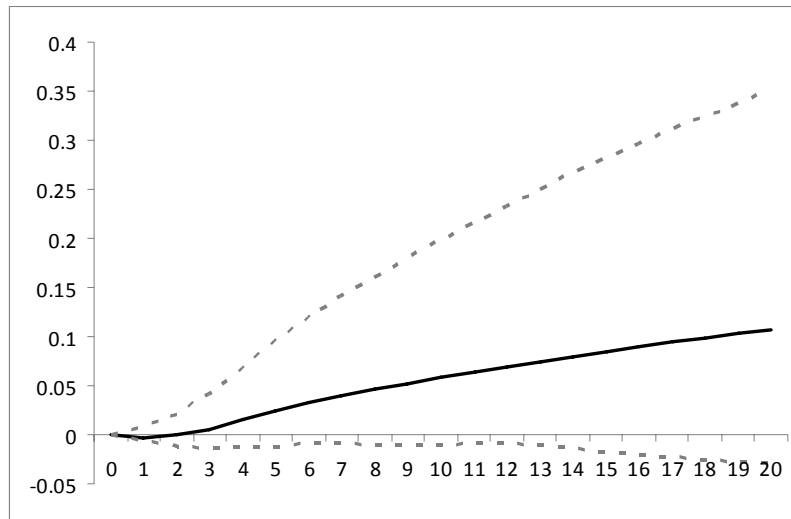
Impulse response function of population to a shock in real per capita GDP
during the Malthusian period: Model 1



Source: Author's calculations

Graph 11a

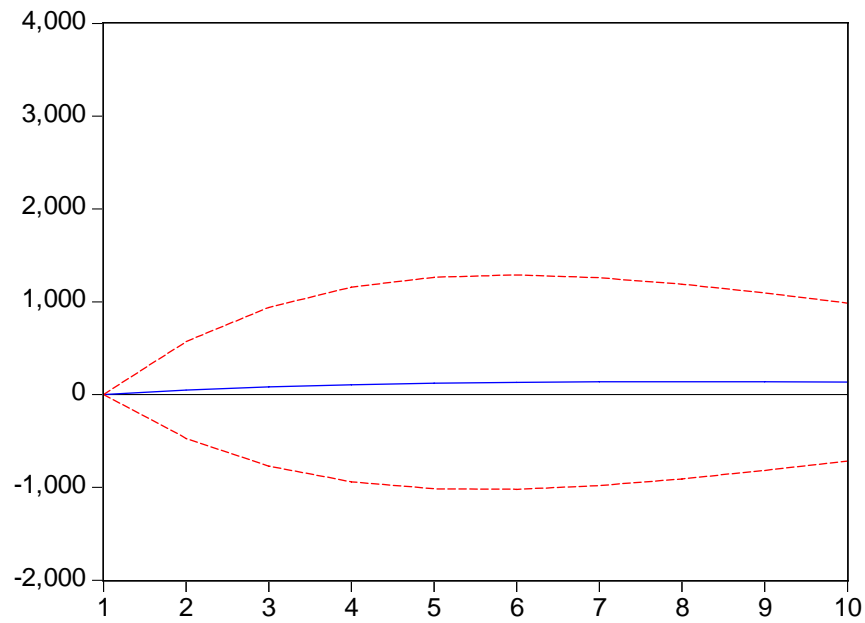
Impulse response function of fertility to a shock in real per capita GDP during the Malthusian period: Model 2



Source: Author's calculations

Graph 11b

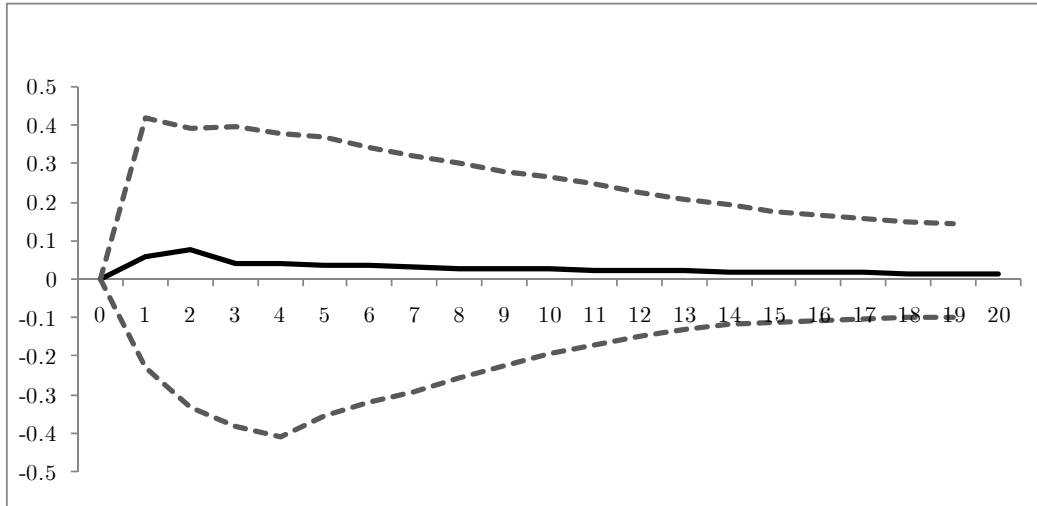
Impulse response function of human capital to a shock in per capita GDP during the Malthusian period: Model 2



Source: Author's calculations

Graph 12a

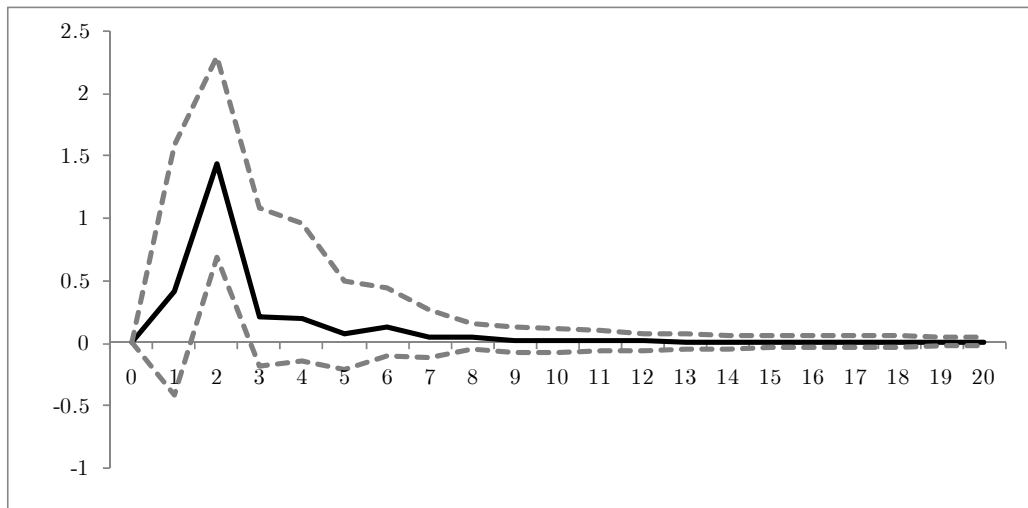
Impulse response function of population to a shock in real per capita GDP during the modern growth regime: Model 1



Source: Author's calculations

Graph 12b

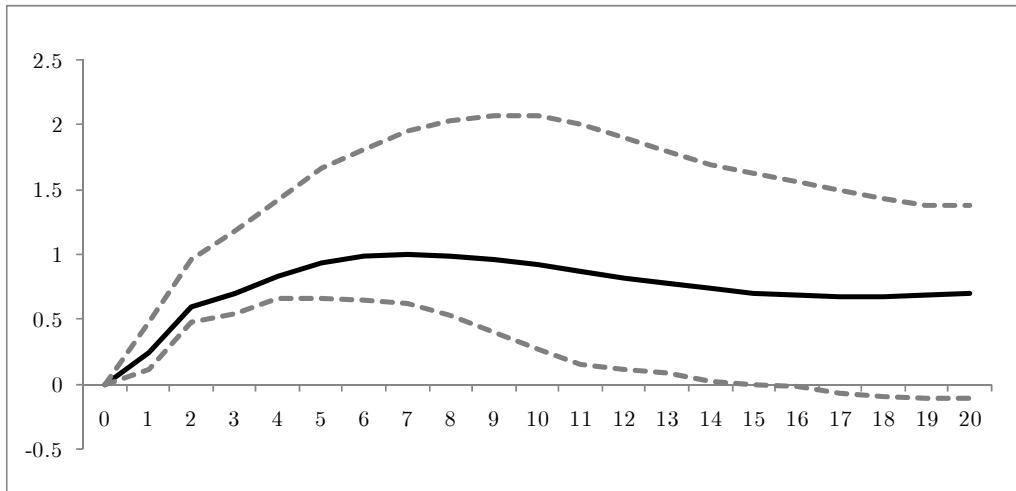
Impulse response function of human capital to a shock in real per capita GDP during the modern growth regime: Model 1



Source: Author's calculations

Graph 13a

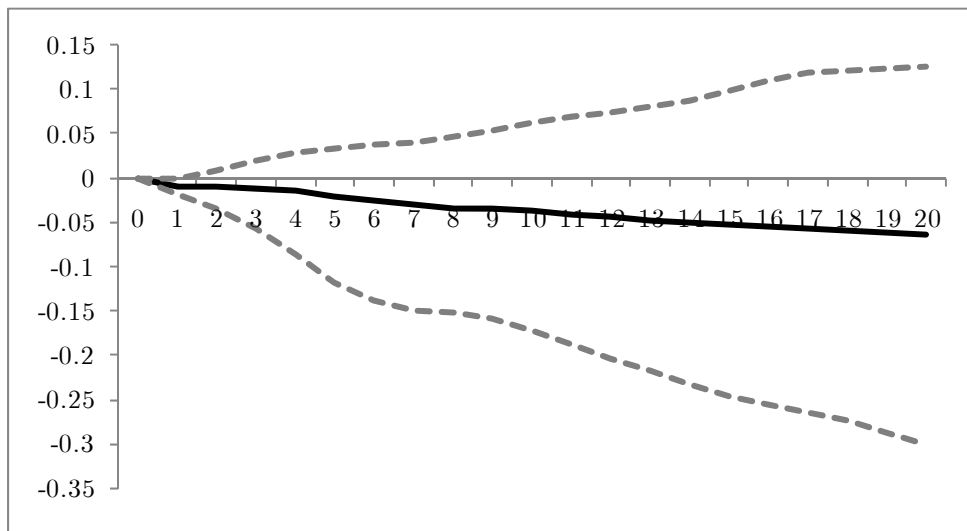
Impulse response function of human capital to a shock in real per capita GDP during the modern growth regime: Model 2



Source: Author's calculations

Graph 13b

Impulse response function of fertility to a shock in real per capita GDP during the modern growth regime: Model 2



Source: Author's calculations

Table 1

Cointegration analysis for the Malthusian period: Model 1

System/Model Lag-length	Eigen values	λ -max	Trace Statistic	Hor	Critical values	
					λ -max	Trace
$\{P_t, RPGDP_t, HC_t\}$	0,41	20,14	34,09	0	13,39	26,70
Model: Drift Lag-Length: 3	0,20	8,33	13,94	1	10,60	13,31

Source: Author's calculations

Table 2

Residual multivariate analysis for the Malthusian period: Model 1

Heterocedasticity (<i>p-values</i>)		Auto-correlation (<i>p-values</i>)				
No Cross T.	Cross T.	L-B (12)	LM (1)	LM (4)	Port (1)	Port (4)
0,053	0,24	0,15	0,83	0,92	0,056	0,24

Source: Author's calculations

Table 3Behavior of the series in the cointegration vector
for the Malthusian Period: Model 1

	P	HC	RPGDP
Exclusion	Included in the cointegration vector	Included in the cointegration vector	Included in the cointegration vector
Stationarity	I(1)	I(1)	I(1)
Weak- exogeneity	END	EXO	END

Source: Author's calculation

Table 4

Cointegration analysis for the Malthusian period: Model 2

System/Model Lag-length	Eigen values	λ -max	Trace Statistic	Hor	Critical values	
					λ -max	Trace
$\{FR_t, HC_t, RPGDP_t\}$	0,35	16,85	29,53	0	13,39	26,70
Model: Drift Lag-Length: 2	0,19	8,28	12,68	1	10,60	13,31

Source: Author's calculations

Table 5

Residual multivariate analysis for the Malthusian period: Model 2

Heterocedasticity (<i>p-values</i>)		Auto-correlation (<i>p-values</i>)				
No Cross T.	Cross T.	L-B (12)	LM (1)	LM (4)	Port (1)	Port (4)
0,05	0,04	0,5	0,97	0,70	0,80	0,84

Source: Author's calculations

Table 6Behavior of the series in the cointegration vector
for the Malthusian period: Model 2

	FR	HC	RPGDP
Exclusion	Included in the cointegration vector	Included in the cointegration vector	Included in the cointegration vector
Stationarity	I(1)	I(1)	I(1)
Weak-exogeneity	END	EXO	END

Source: Author's calculation

Table 7

Cointegration analysis for the modern growth regime: Model 1

System/Model Lag-length	Eigen values	Trace Statistics	Ho:r	Critical Value
$\{P_t, RPGDP_t, HC_t\}$	0,33	26,29	0	29.79
Model: Drift Lag-Length: 3	0,20	5,62	1	15.49
	0,002	0,12	2	3.84

Source: Author's calculations

Table 8VAR Residual multivariate analysis for
the modern growth regime: Model 1

Heterocedasticity (<i>p-values</i>)		Auto-correlation (<i>p-values</i>)			
No Cross T.	Cross T.	L-B-1	LM-4	Port (1)	Port (4)
0,09	0,34	0,96	0,35	0,59	0,09

Source: Author's calculations

Table 9

Cointegration analysis for the modern growth regime: Model 2

System/Model Lag-length	Eigen values	λ -max	Trace Statistics	Ho:r	Critical values	
					λ -max	Trace
$\{FR_t, HC_t, RPGDP_t\}$	0,37	22,50	30,86	0	13,39	26,70
Model: Drift Lag-Length: 3	0,16	8,36	8,36	1	10,60	13,31

Source: Author's calculations

Table 10Residual multivariate analysis for
the modern growth regime: Model 2

Heterocedasticity (<i>p-values</i>)		Auto-correlation (<i>p-values</i>)				
No Cross T.	Cross T.	L-B	LM (1)	LM (4)	Port (1)	Port (4)
0,15	0,10	0,4	0,86	0,56	0,04	0,13

Source: Author's calculations

Table 11Behavior of the series in the cointegration vector
for the modern growth regime: Model 2

	FR	HC	RPGDP
Exclusion	Included in the cointegration vector	Included in the cointegration vector	Included in the cointegration vector
Stationarity	I(1)	I(1)	I(1)
Weak- exogeneity	EXO	END	END

Source: Author's calculation